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Summary:

At nearly tangential incidence of light the non-linear or multiphoton photo-effect on Ag, Au and Ni was studied in the power density range 24-120 MW/cm². The experimental values of the photo-current can be approximated by a power function. The exponent of this function increases with the power density.

In two previous papers [1], [2] we reported on experimental investigations of some properties of the non-linear or multiphoton photo-effect. In [1] the polarisation dependence of the non-linear photo-electric emission, in [2] the photo-current I as a function of the power density P of the laser beam were studied. Our experimental method and procedure were later confirmed by the theoretical considerations of Bunkin and Prokhorov [3]. In the investigations reported in [1] and [2] the quantum energy of the laser beam was $h\nu \approx 1,8$ eV, i.e. much less than the work function $A_{Ag} = 4,8$ eV of the silver target used. In [2] it was shown that the experimental values of the photo-current I can be approximated by the function $I = KP^\alpha$, indicating that α increases with increasing power density P and the minimum value of α at the threshold of the non-linear photo-effect corresponds to the theoretical expectations; namely it is $\alpha_{\min} \approx \frac{A}{h\nu}$. In the present paper we report on measurements showing the dependence of the non-linear photo-effect on the target material and power density P using the same experimental arrangement as in [2], i.e. tangential incidence of light pulses /duration $\tau \approx 25$ nsec/; as targets silver, gold and nickel were used. The power density of the beam was varied in the range 24-120 MW/cm², which corresponds to a power density range 2-10 MW/cm² on the target surface. The work function of silver and gold are practically equal, i.e. $A_{Ag} \sim A_{Au} \approx 4,8$ eV, while that of nickel is $A_{Ni} \approx 5,1$ eV. The results shown in Fig.1. confirm that α increases with P and that the minimum value of the exponent observed is $A/h\nu$.

For silver and gold the approximations $I_{Ag} = I_{Ag}(P)$ and $I_{Au} = I_{Au}(P)$ almost coincide within the experimental error. At the lower end of the power density

range investigated the values of the exponents are practically equal, $(\alpha_{Ag})_{\min} \sim (\alpha_{Au})_{\min} \sim 3$, and agree well with that determined by Logothetis and Hartman [4] for gold. Owing to the lower yield of silver, however, the measuring error of the photo-current in the case of silver target is larger than for gold and therefore the precise determination of the initial slope of I_{Ag} needs further measurements. The observation of the non-linear photo-effect, even at higher power densities on the target surface than the limit power density of 1 MW/cm^2 given by Logothetis and Hartman in [4], seems to be due to that the electric field strength was adjusted to the optimum direction. That means that the incidence of the beam was nearly tangential and the direction of polarisation of the electric field strength was perpendicular to the surface of the target so that the whole electric field was directly contributing to the non-linear photo-electron emission.

At higher power densities $/P \gtrsim 45 \text{ MW/cm}^2/$ we get for the exponent $\alpha_{Ag} \sim \alpha_{Au} \sim 6$. This value is less than that given in [2]. This deviation can be attributed to the non-linear response of the calibrated detector used for the determination of P during the measurements reported in [2]. The values of the results given in [2] corrected for this non-linearity fit well to the results of our present measurements /see Fig.1./, with exception of the value at $P = 30 \text{ MW/cm}^2$. The increase of the exponent in the range $P \gtrsim 45 \text{ MW/cm}^2$ may be due to the fact that at higher power densities the effect observed becomes increasingly non-linear /i.e. more and more photons are contributing to the emission of a single photo-electron/. In this power density range however, the possibility of some contribution of thermal effects to the effect observed, cannot be excluded, although the duration τ and the intensity of the light pulse practically do not exceed the limit value for occurrence of thermal effects given in [3].

Our assumption that even at higher power densities the electron current observed is produced mainly by the non-linear photo-effect is further supported by the considerable energies of the emitted electrons /see [2]/.

Some decrease observed in the slope of the functions I_{Ag} and I_{Au} at the highest power densities needs further investigation.

Using nickel target the electron pulse was observed to be distorted and considerably longer than in the case of Ag and Au. This seems to indicate the contribution of thermal effects to a greater extent. Therefore, the results for Ni target in Fig. 1. cannot be directly compared with those for Ag and Au.

Since, according to the theory [3], with nickel target thermal effects are expected to contribute to the electron current for much shorter $/\sim 1 \text{ nsec}/$ light pulses than in the case of Ag and Au, the distortion of the pulse shape may be explained.

This finding with nickel, the effects observed by Logothetis and Hartman above their 1 MW/cm^2 power density limit, and the calculations of Bunkin and Prokhorov suggest to investigate the dependence of the signal produced by the emitted electrons on the angle of incidence. Such experiments and also further investigations of the energy distribution of the emitted electrons are in progress.

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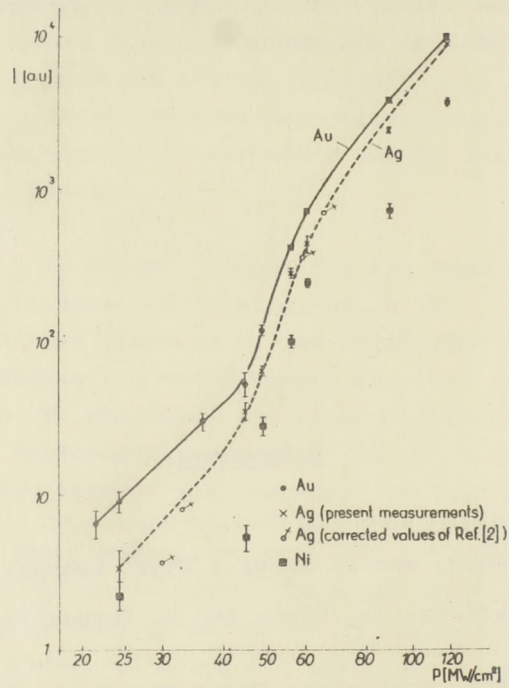


Fig. 1.

Dependence of the electron current I on the power density P of the laser beam for gold, silver and nickel.

